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16. Summary/Notes

In this paper some selected recent applications of satellite remote sensing in the areas of Agronomy, Geology, Oceanography, Geography, Environment and Cartography are presented. A brief description of the Brazilian Satellite Remote Sensing is also given.

17. Remarks

BRAZILIAN SATELLITE REMOTE SENSING PROGRAM
SELECTED RECENT APPLICATIONS

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CHAPTER I

INTRODUCTION

It is not by hazard that Brazil has a large and important program on space applications. Territory integration and the necessity of obtaining low-cost reliable periodic information about it are the key factors responsible for the massive utilization of data collected and/or transmitted by the so-called application satellites, in the areas of meteorology, remote sensing and telecommunications.

The Brazilian territory is not yet well known, mainly with respect to its natural resources. With an area of a little over 8,500,000 square kilometers, it presents large regions of difficult acess and low population density (for example, the Amazon Forest occupies a surface of about half of it), making hard, if not impossible, to study it by conventional methods. The dynamical character of the processes that contribute to the social and/or economical development of the country and/or to its security asks for a data collection system that presents four basic ingredients: can be applied for the whole territory; has a low cost/benefit ratio; has an almost real-time data utilization character and can be used many times (periodicaly, if possible).

Consequently, satellite remote sensing which allows the periodic survey of large areas very rapidly and at relatively low cost became an effective tool for Brazil to increase the knowledge about its renewable and non-renewable resources and to monitor the modifications that take place on its environment.

In the last decade, many institutions in Brazil and specially the Instituto de Pesquisas Espaciais (INPE) have dedicated a great effort in order to develop methodologies for the application of remote sensing data in many important areas. Some of the recent results are discussed in this paper (chapter III). For the sake of completeness, a brief description of the Brazilian Remote Sensing Program is also presented (chapter II).

CHAPTER II

BRAZILIAN REMOTE SENSING PROGRAM

The Brazilian remote sensing activities started in 1968. However, it was during 1970 that two important studies were done at INPE. The first one was related to the instalation of a LANDSAT receiving and processing station in Brazil and the second was dedicated to the survey of mineral resources of part of the Amazon region (about 44,000 Km^2) using a side-looking radar as the main source of information. These initial studies gave birth to the two major existing remote sensing programs in Brazil: the Satellite Remote Sensing Program, whose leading organization is INPE and the Radar (RADAMBRASIL) Program, whose leading organization is the National Department of Mineral Production (DNPM).

The Radar Program has as objective to systematically survey the natural resources of the whole national territory in a level of detail compatible with a 1:1,000,000 scale, focussing on geology, geomorphology, soil, agriculture aptitude, ecology and potential land use.

The Satellite Remote Sensing Program has as main objectives the reception, processing and dissemination of remote sensing data (today basically LANDSAT data) and the development of new methodologies for the application of these data in the survey and monitoring of natural resources (mineral, agronomical, forest, hydric, oceanographic), observation of the environment, monitoring land use, map and thematic cartography, regional and urban planning, polution, disaster forecast and monitoring, among others. Special emphasy is given to projects related to national priorities which today include Agriculture and Energy.

The transference to the user community of the know-how, technology and related methodology developped in the processes is a constant preocupation in the Program. Besides offering on-the-job training, especialized seminars and graduate courses, INPE always

forces the participation of the user institution in the methodology development phase for the transfer to be more effective.

The main available facilities are a LANDSAT tracking and receiving station (located at Cuiabã-city covering, consequently, great part of South America as shown in Fig. II.1), and LANDSAT processing station and distribution center (located at Cachoeira Paulista), all operational meteorological satellites (GOES and TIROS-N) receiving and processing stations (located at São Josẽ dos Campos), two automatic image analysis systems and a two-engine Bandeirante aircraft equipped with several sensors.

Since the beginning of the Satellite Remote Sensing Program, in 1973, the number of images produced and the number of users have grown steadily. In terms of image production, Brazil is second in the world and the number of users (mostly institutions) has already crossed the 1,500 mark, some of them are foreign (see Tables 1 and 2 for details).

Up today a great number of application methodologies have been developed, mainly by INPE (which has an application remote sensing muldisciplinary group of about 100 experts) in the areas shown in Table 3. In the next Chaper, a brief description of some recent results obtained in each one is presented.

Today, remote sensing is a reality in Brazil. Due to the spetacular utilization of remote sensing satellite data, two further steps were already taken by the Brazilian Government.

The first one is the decision to upgrade the existing LANDSAT reception and processing stations to receive and process MSS and Thematic data from LANDSAT-D satellites as well as SPOT data. A commercial contract has being already signed by INPE with the French Sociẽtẽ Europẽenne de Propulsion (SEP) for that purpose.

Fig. II.1 - LANDSAT Cuiabá ground station coverage.

TABLE II.1

NUMBER OF IMAGES DISTRIBUTED PER YEAR

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981(*)
IMAGES	323	1,230	2,094	7,564	10,045	18,049	19,051	11,400	1,881
CCT	-	10	55	141	132	141	146	176	40

(*) March, 1981

TABLE II.2

NUMBER OF USERS

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981(*)
TOTAL NUMBER OF USERS	3	27	69	156	301	646	1161	1045	1063
BRAZILIAN USERS						502	935	902	909

(*) March, 1981

TABLE II.3

APPLICATION PROGRAMS

AREA	PROGRAM
Agronomy and Forestry	Crop Survey Soils Survey Natural Forest Survey Deforestation Reforestation
Geology	Regional Geological Mapping Mineral and Oil Exploration
Oceanography and Hydrography	Marine Fishing Charts Physical Oceanography Hydrography
Geography	Potential Land Use Actual Land Use Urban Area Expansion
Environment	Pollution in Water Bodies Sedimentation in Water Reservoirs Desertification
Cartography	Mapping Aeronautical Charts

The second is related to the project, construction, integration and operation (all done by INPE with the effective participation of Brazilian industries) of two remote sensing satelites, which will be launched by a Brazilian launcher in the 1987-1990 period. They will have a near-polar circular heliosynchronous orbit of approximately 650 km and total mass of about 250 kg. The remote sensing camera will use CCD detectors and the images will be produced in four channels with near 50 meters resolution.

CHAPTER III

SELECTED SATELLITE REMOTE SENSING APPLICATIONS IN BRAZIL

3.1 - INTRODUCTION

In this Chapter some selected recent satellite sensing applications are presented in the areas of Agronomy, Geology, Oceanography, Geography, Cartography and Environment (Table III.1). The applications on Forestry, will not be discussed here since they were analysed in another paper (*). The names of the authors of each application are also presented.

TABLE III.1

SELECTED SATELLITE REMOTE SENSING APPLICATIONS

AREA	APPLICATION	AUTHORS
Agronomy	Crop Forecasting	Nelson J. Parada Renê A. Novaes
Geology	Mineral Exploration	Paulo R. Menezes Waldir R. Paradella Juêrcio T. Mattos
Oceanography	Fishing Charts	Sydnea Maluf
Geography	Land Use	Magda A. Lombardo Madalena Niero Evlyn M.L.M. Novo Celina Foresti
Environment	Sedimentation in Water Reservoir	Tânia M. Sausen
Cartography	Mapping and Aeronautical Charts	Mârcio N. Barbosa Josê L. B. Aguirre

(*) *See, N.J.Parada, "Remote Sensing in Forestry: Application to the Amazon Region", presented in this Seminar.*

3.2 - A CROP FORECASTING SYSTEM BASED ON EARTH OBSERVATION SATELLITES
(by Nelson J. Parada and Renẽ A. Novaes, INPE)

In general, importing and exporting countries manage a delicate balance between supply and demand, antecipating the determining factors as far in advance of transactions as possible. In such situations, timely information relevant to antecipate resupply from new harvests is crucial. Without timely and reliable crop demand and supply information, an exporting nation may impose a costly, but unecessary, moratorium on its grain sales. Importing countries with limited storage must have early forecasts of their own supply positions to make effective purchasing decisions. Distribution and transportation arrangements within and between export and import nations benefit greatly when accurate crop forest and food supply information is available. Agricultural production is highly dynamic in nature and dependent on complicated interactions of prices, weather, soils and technology. The outlook can and usually does change as these ingredients are alterated either through natural changes or as a result of man's decisions. While decisions have been and will continue to be based upon whatever information is available, there is a continuing need on the part of decision-makers, in both public and private sectors, for improving information.

Thus, in a country like Brazil, where Agriculture and Energy are national priorities, Crop Survey and Forecasting become crucial and basic information for the Government, both from the economical, strategical and security point of views.

The large Brazilian territory, with regions presenting different characteristics and climate and where adverse meteorological phenomena such drought, frost and flood commonly occur, makes the National Crop Forecasting a different task to attent.

However, the repeatitivity, real-time data acquisition, reasonable costs and national coverage properties of the Earth observation satellites have made them perfect tools for solving problems like the one mentioned above.

The main objectives of the proposed system is to provide pre-harvested estimate of crop production with an accuracy of 80%. The main information sources of this system are Earth observation satellites. In what follows, it will be refered as the satellite crop forecasting system.

The crop yield of a certain region can be defined as the product of two variables: the cultivated area and the average productivity of that region. For the area estimation LANDSAT images will be used and meteorological satellite data will provide, when possible, the climatological parameters that enter in the productivity equation.

Although designed to complement the existing conventional system, the satellite crop forecasting system presents some advantages, as:

- reduction of ground truth data
- can be applied to the whole territory
- presents high monitoring capacity (LANDSAT satellites have a 18 days periodicity and meteorological satellite data and daily available).

It is important to keep in mind that, in Brazil, only for the more developed states there exist a reasonable conventional crop forecasting.

During the first part of the project, production estimates of sugar-cane, wheat and soybeans of São Paulo and Paranã States will be made (Figure III.1). Experimental studies are planned for crop year 1982/83 with the objectives of:

1) improving the accuracy of estimation;
2) choosing the time frame during which period crop estimate is available with an acceptable error.

Crop estimates for the following years will include other productive areas. Also, the system will be expanded to enbody new important crops.

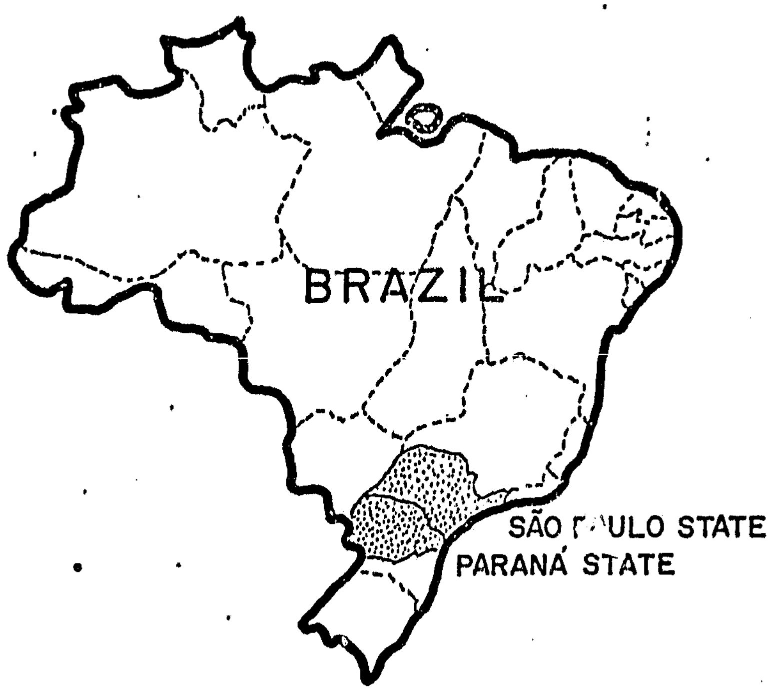

Fig. III.1 - Study area for the first part of the Crop Forecasting System based on Earth observations Satellites (for sugar-canes, soybeans and wheat, starting crop year 1982/1983).

Some previous results have been already obtained for crop area estimation.

In forestry studies, a computer-aided classification method was used to estimate areas of Pinus spp. and Eucalyptus spp. The errors of estimation were less that 8%. This classification method is today being used in a quasi-operational national scale.

For wheat, three study areas in Rio Grande do Sul State were selected. Using LANDSAT MSS data and infrared aerial photographs as ancillary information, the spectral response patterns of wheat were defined.

For sugar-cane, inventory studies were carried out in São Paulo State for crop year 1978/79 and 1979/80 (São Paulo State is responsible for near 70% of the national sugar-cane production). Comparison between the area estimate using LANDSAT imagery and that given by the Agriculture Ministriy (using conventional methods) showed a difference of 12% for crop year 1978/79. In both cases, sugar-cane distribution map was derived. The mapping accuracy was 90% for that year.

The methodology used in the studies were basically the same: the spectral, spatial and temporal information of LANDSAT imagery or CCTs were correlated to data provided by infrared aerial photography or field study. Analysis procedures involved two steps: 1) using conventional photointerpretation techniques on imagery, 2) computer-aided pattern recognition of CCTs.

All projects were developed with the cooperation of organizations which are responsible for the administration of agriculture productions of the corresponding States. Researchers of those organizations are trained at INPE to get acquaintance with the remote sensing techniques.

A basic consideration for crop forecasting study is to provide accurate and timeliness crop information which meet the necessities of agribusiness sectors. It is believed that participations of governmental or private sectors in the implantation and development of a crop forecasting system may resolve some management and financial problems encountered in the above mentioned studies.

However, some technical problems were caused by the specific Brazilian conditions and its agricultural practices. For instance:

1) the large Brazilian territory extends from Equator to latitude 33^{o}S (Rio Grande do Sul State); generally speaking, advanced technology is primarily used to some extent only in the southern part of the country;

2) small fields in areas of intensive agriculture or ondulated topography may difficult to identify owing to the present LANDSAT resolution of .4 ha (one pixel);

3) besides the border problem of small fields the different spectral responses of one crop caused by different cropping practices (which hinder crop identification), the coincidence of the growth period with rainy season may further difficult data acquisition due to cloud cover.

To overcome these problems and taking into considerations the experience gained in previous projects, the following method should be used:

- stratification of the study area into homogeneous zones, considering the climate factors, soil types, cropping practices, crop densities, topography, etc.,

- each stratum should be divided into segments of a pre-defined size,

- a part of the segments within each stratum is selected randomly and designated as sampling units for training (SUT),

- the crop area of each selected SUT will be estimated using 1) and interative multispectral image analyzer (Image 100) and multitemporal CCTs 2) visual interpretation on infrared aerial photographs,
- based on the area estimates from LANDSAT and aerial photographs of SUTs, a regression equation can be derived and its correlation be used for the correction of crop area estimate in the stratum from LANDSAT data. Crop area will then be combined from strata and error of estimation calculated.

In 1983 LANDSAT "D" data will be available for Brazil. The additional channels and the better resolutions of thematic mapper may improve crop identification and give more accurate area estimate.

As mentioned before, application of this system to other states and crops will be studied starting from crop year 1985/86.

3.3 - MINERAL EXPLORATION

(by Paulo R. Menezes, Waldir Paradela and Juẽrcio T. Mattos, INPE).

One of the objectives of INPE's Remote Sensing Program is the application of remote sensing techniques to studies leading to the definition of potential mineral deposits.

Brazilian application of remote sensing in mineral exploration initiated in the early 70's with a few aircraft missions (with photographic equipment) over mineralized targets.

With the advent of the LANDSAT program, research was aimed to determine the potentiality of its products in providing information on the lithologic and structural controls of wellknown ore deposits. Later, studies were directed towards smaller areas of interest.

The acquisition of the GE-Image 100 in 1975, stimulated efforts in systematic mineral search with computer processing programs, such as digital enhancement and supervised and non-supervised classification methods.

During the last decade, remote sensing has been applied to studies dealing with deposits of bauxite, lead and zinc, tin, marbles, iron, clay, and radiactive material, located in different geologic environments of Brazil. The precise role that remote sensing has played in location new mineral sources is difficult to evaluate. The following studies were selected for detailed discussion.

Hydrocarbon Prospection

Increasing demands for secure oil and gas supply determine that all possible techniques should be used for locating new energy sources.

Therefore, several superficial areas of the intracratonic Phanerozoic Parana Basin (Figure III.2) have been searched for oil trap indicators utilizing LANDSAT and RADAR imagery, since conventional geophysical methods are not satisfactory due to the Mesozoic basaltic blanket.

The objecitve of this work is the development and application of a methodology for visual interpretation of images, with the purpose to identify and classify anomalous morpho-structures indicated by the drainage system and element of relief.

The criteria utilized in the classification of the morpho-structures are: a) identification of anomalous radial and annular drainage patterns; b) dip indicators and discontinuities in sub-horizontal beds as shown by asymmetric drainages system; c) delineation of drainage elements strongly affected by uni-directional structures (homologous zones), that could be interpreted as reflecting deep faults with large displacements of drainage and relief, interpreted as reflecting deep fracture zones and faults.

The integration of these elements helped in the definition of the main lines that characterize the geometric pattern of the anomaly reflecting the buried structure.

The results showed that within each terrain block covering 11.000 km^2, an average of about 10 morpho-structural anomalies could be identified and classified as potential areas for further detailed studies toward the detection of oil traps. These anomalies characterize structural domes and basins that have been confirmed by other conventional methods.

The work was planned and carried out as a joint project between INPE and the São Paulo State Oil Companhy - PAULIPETRO. Management and financial support was under the responsability of the contracting company.

Fig. III.2 - Paranā Basin.

The images used were LANDSAT 5, 6 and 7 bands at 1:500.000 and 1:250.000 scales, and RADAR mosaics at 1:250.000 scales.

The results obtained were compared with conventional interpretation of air-photos at 1:50.000 and 1:25.000 scales and field work.

The entire work for a total area of 100,000 km^2 was done by a 6 men team and took 6 months.

With no doubt, remote sensing when applied to oil exploration of large areas has showm to be highly important. Besides giving extra geological information, remote sensing is essential in the integration of geological and geophysical data needed in barehole location, at a cost of about one dollar per square kilometer.

Titanium Mineral Exploration

The discovery of new titaninum deposits is very important for Brasil, since almost 80% of industrial consumption is imported.

Because of that, a program for the search of titanium ore (primary ilmenite) was developed by INPE in cooperation with a private company (Figure III.3) in the Floresta region, Pernambuco State.

Using supervised automatic classification, a maximum likelihood criterion was used to classify an area of almost 500 km^2 in a flat semi-arid region, where previous geological information indicated the presence of a small ilmenite deposit related to a basic-ultrabasic sequence intercalated with granitic-migmatetic rocks of Precambrian age.

The application of automatic classification to LANDSAT data revealed, in the entire area, more than 600 "alarmed areas".

During the period of October 1978 up to January 1979 only a part of those areas were checked out. As a consequence 56 titanium occurences were confirmed and 4 new ore deposits were discovered.

The automatic data processing was done by the staff of geologists of INPE with the participation of one geologist from the mineral exploration company.

The evaluation phase, including field work, petrography and geochemical analysis, were realized under the responsability of the mineral company.

Most of the cost of the research was underwritten by the contracting company (Construtora Norberto Odebrecht S/A).

The digital LANDSAT MSS data used were standard CCT and the automatic interpretations were done using the GE-Image Analyser.

A supervised algorythm for automatic classification (MAXVER Program) was used in the classification phase, after a preliminary processing including geometric rectification to remove image skew was performed.

Conventional panchromatic photographs were used first to locate training areas in the LANDSAT Image and mainly during the field work to access the alarmed area. A detailed field work program to check the suggested areas included soil sampling for later petrographic and geochemical analysis. In the area where good economic perspectives existed, the evaluation was completed by a drill hole program.

During the development of the research (almost seven months), the total cost of the automatic processing phase was estimated near U$ 3,000 (1978). The rapid overview of the titanium potentiality of the Floresta Region using a low cost methodology, can be appointed as one of the principal results obtained.

Fig: III.3 - Floresta Region in Pernambuco State.

The alarmed areas appear to be caused by the soil color and rock fragments stained by oxides of iron and manganese.

Large quantities of Fe^{+++} normally associated with ilmenite would be the most important factor of the spectral response, principally by the high absorption that Fe^{+++} causes in the near infrared region, contrasting with the high reflectance of the sterile granitic rocks in the same spectral range.

The methodology can be applied with success in the definition of similar deposits in the same environmental conditions, such as an arid region, where the influences of the relief and vegetation are minimized and the alteration products of rocks remained in situ.

3.4 - REMOTE SENSING APPLIED TO FISHING CHART MODELS

(by Sydnêa Maluf, Instituto de Pesquisas Espaciais)

Since pre-historic times, fishing constitutes a dominant activity of mankind, because of the need for obtaining food. The establishment of an increasing effort in the search for a better, rational and economical utilization of fishing resources, has been the preocupation of professionals and scientists involved in fishing, until present days.

The remote sensors open a new field of applications which allows an assessment of the potencial of marine resources in a larger area in real time.

This work presents a methodology of the application of remote sensing techniques as an aid to the inventorying, monitoring and in the near future, the prediction of fish catches.

The basis of the work is the development of a simple Fishing Chart Model, done by utilizing oceanographic, fishing and remote sensing data, for the detection of the best fishing areas for sardine catches (*Sardinella brasiliensis*).

The studied region is located in the Shoutheast Coast of Brazil, between 21°45'S and 25°00'S latitudes and 040°50'W and 047°00'W longitudes, along the Rio de Janeiro and São Paulo States (Figure III.4).

The Model includes the utilization of the images of the VHRR (Very High Resolution Radiometer) sensor of NOAA's satellites for the obtention of data leading to the identification of some oceanographic characteristics of sea water for the detection of fishing areas for sardines.

The Model utilizes data from the sea water surface such as: temperature (°C), salinity(‰), oxygen content (mℓ/ℓ), phosphate (μg at/ℓ), fishing catch data (kg/catch), for the period of six months (july to december).

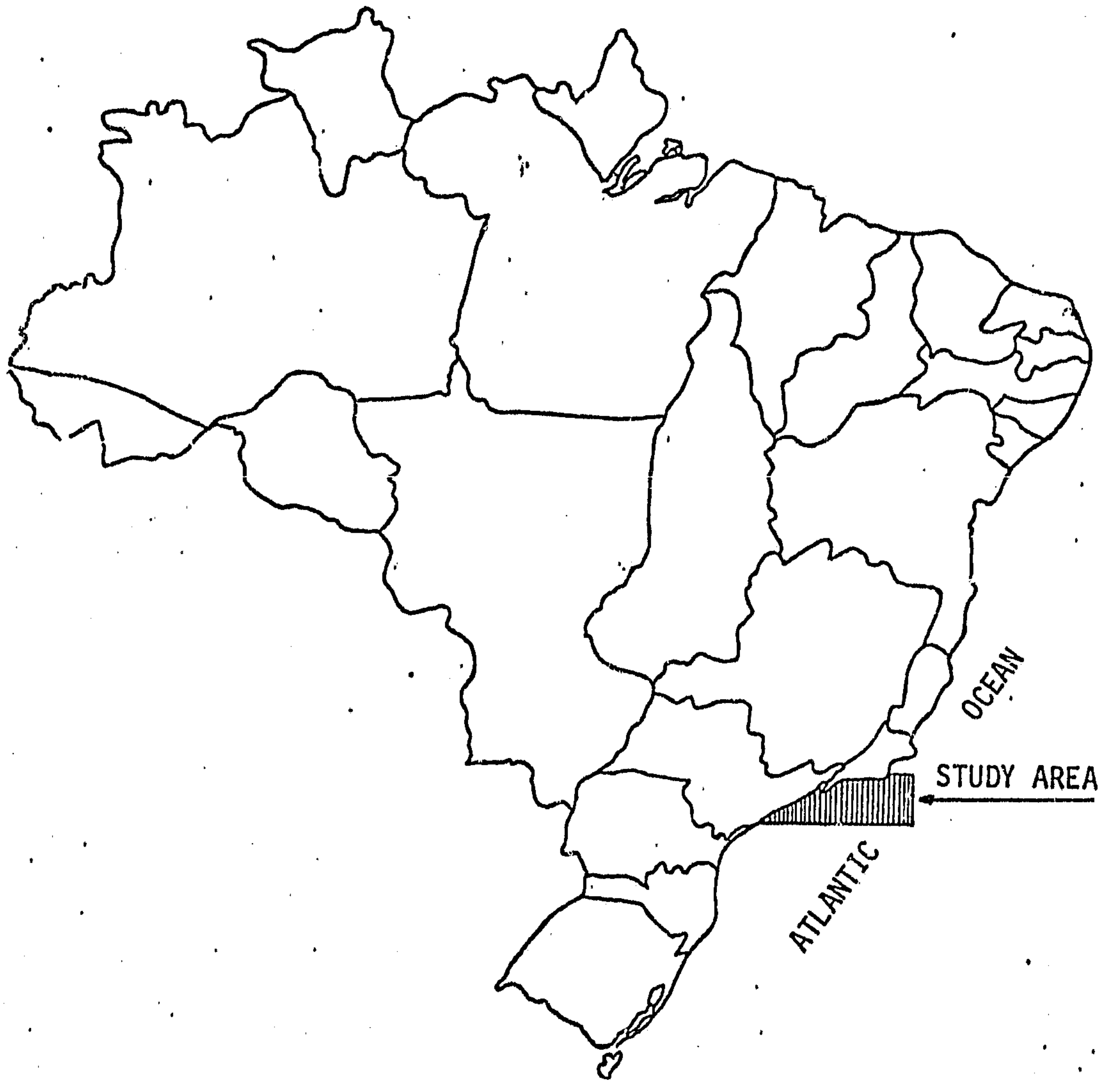

Fig. III.4 - Fishing Chart Study Area.

With the above data as basis, monthly charts of the distribution of the parameters were prepared using mean values plotted in the Chart nº 23900 of the Brazilian Navy Hydrographic Service (DHN) (1:1,000,000). These charts were superimposed and the relationship between the parameters were established, month to month, and the best fishing areas for sardine were delineated, as a function of the largest catch indexes and the associated oceanographic parameters. In that form, a final monthly chart containing different areas distributed along the coast of the studied region, were obtained. Figure III.5 shows for September one of these fishing charts, containing the best fishing areas determined with the methodology developed in the project.

Each Fishing Chart contains: the total number of the best fishing areas; their locations in relation to local depth and distance from the coast; the dimensions $(Km)^2$ of each area; the approximate value in kg/catch a sardine and the values of associated oceanographic parameters.

With respect to the utilization of remote sensing information, a qualitative (visual) comparison was done between an infrared VHRR image of NOAA-5 satellite of September 29, 1977 (orbit nº 5282, time 10:43 GMT), and the surface temperature of oceanographic chart obtained with the mean values of the temperature for September. It was observed that the clearer areas of the image (colder water), corresponded to regions of temperature less than 22°C in the oceanographic chart, and the darker areas (warmer water), corresponded to temperature greater than 22°C in the oceanographic chart.

Respectively to the localization of the best fishing areas for September, it was observed that areas 1 and 2 (localized between Cabo de São Tomé and Cabo Frio and in front of Baía de Guanabara, respectively) were located in the region of low temperature (clear areas in the image). Those areas were defined before by a minimum temperature (less than 21°C). The third area was localized between Ilha Grande and Ilha de São Sebatião in a region of warmer water in the image of NOAA-5, and was defined before by a maximum temperature (between 22°C and 23°C).

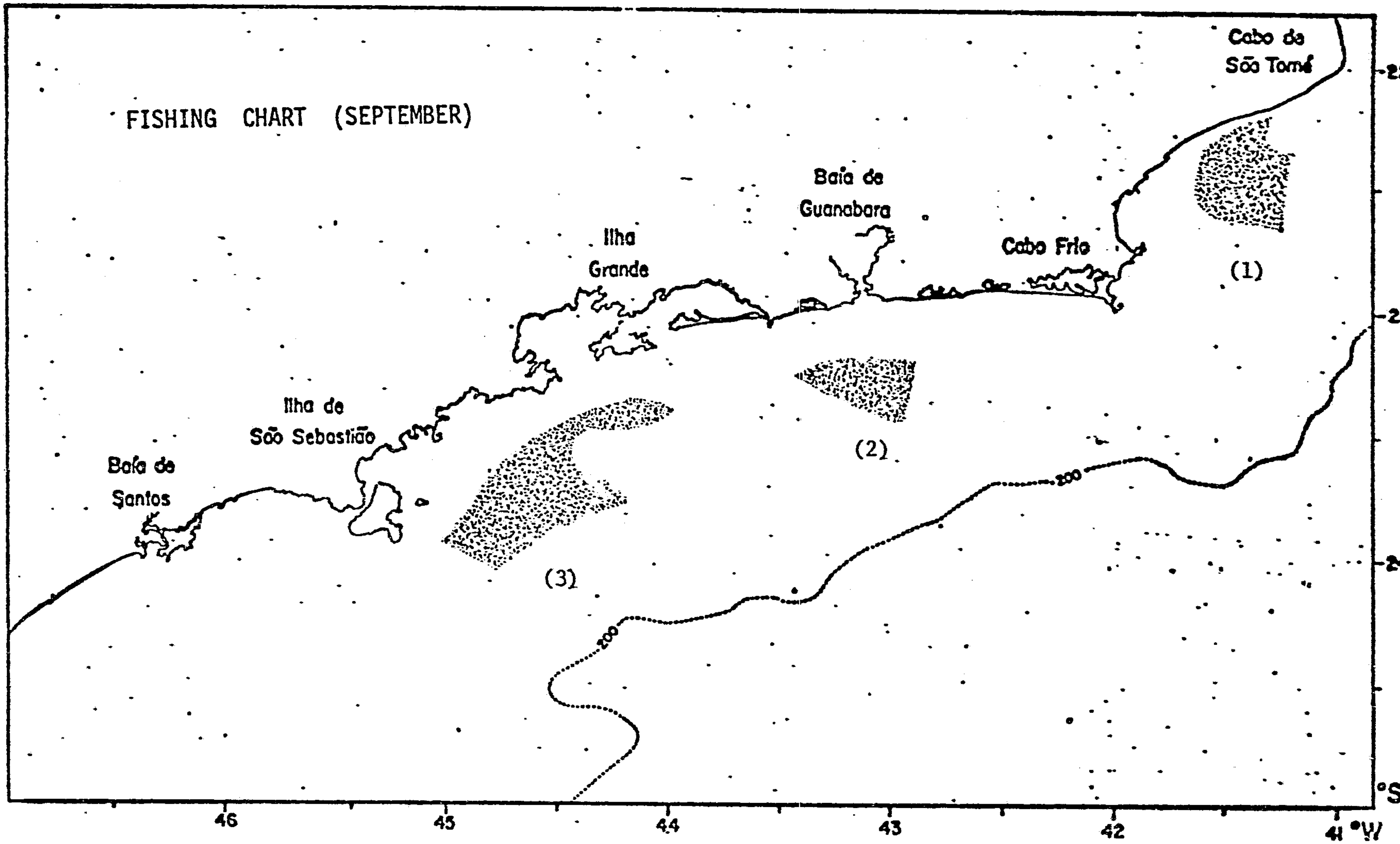

Fig. III.5 - Fishing Chart (September).

Figure III.6 shows the isotherms obtained through the GOSSTCOMP Project (Global Ocean Sea Surface Temperature Computation), of NOAA-4 for September 3, 1975. Comparing this chart and the surface temperature on the oceanographic chart, it was observed that the area number 1 (an asteric in the figure), was localized in the regionwhere the temperature given by the NOAA-4 satellite was 20°C and the temperature given by the oceanographic chart was 21°C. In the area number 2 (also an asterisc in the figure), the temperature given by NOAA-4 satellite was 21°C and the temperature given by the oceanographic chart was between 22°C and 23°C. So, the difference between the temperaturesgiven by the satellite and by the the oceanographic chart was ± 1°C, in areas number 1 and 2.

These results show the usefullness of temperature data obtained from infrared satellite images, in the localization of the best fishing areas. The sea surface temperature charts obtained through remote sensing data can be considered as *basic charts* for the inventorying and monitoring of marine resources.

Using this First Model of Fishing Chart for Sardine, as a basis, models for other pelagic species of economical importance, existing along the Brazilian coast, were prepared. As a consequence Models for the best fishing areas for tuna and skipjack were obtained.

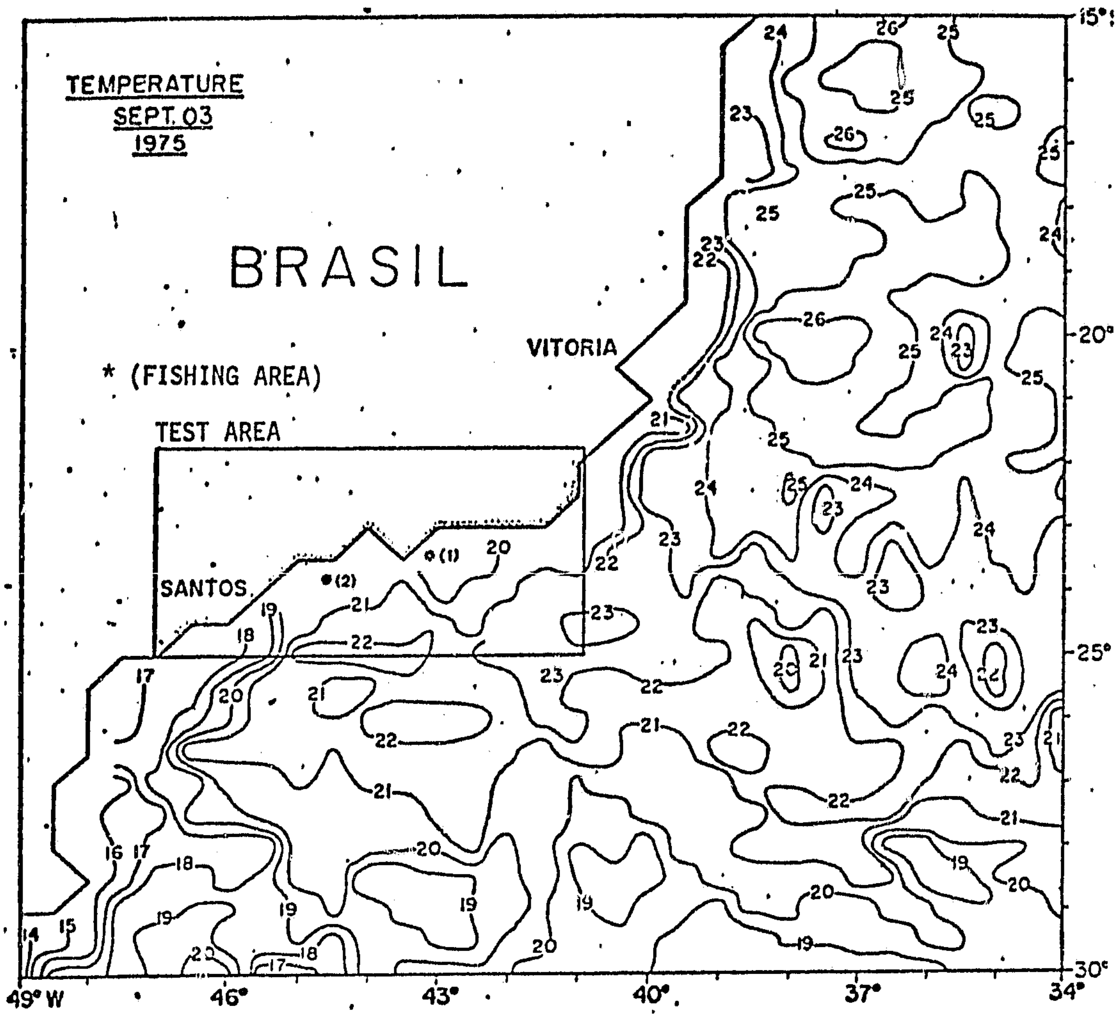

Fig. III.6 - Isotherms obtained through the GOSSTCOMP Project.

3.5 - LAND-USE IN THE PARAIBA VALLEY - SÃO PAULO STATE, BRAZIL

(by Magda A. Lombardo, Madalena Niero, Evlyn Márcia L.M.Novo and Celina Foresti, Instituto de Pesquisas Espaciais)

During the last decades the interest of governmental agencies to obtain information about land-use has increased. Their main concern has been related to the catastrophic effects caused by the irrational soil use.

In Brazil, the interest for land-use planning is very recent. There are very few data available which allow an analysis of the changes in land use patterns, as well as their effects on spatial organization.

Considering these problems, the main objective of the project was to evaluate the potential of LANDSAT system in providing information about land-use.

The systematic obtention of land use data through orbital imagery will allow a periodical registration of changes of soil use and the changes of the area under study.

The Paraiba Valley was selected as a study area because of the different types of soil occupation and also because it is a region that has been undergoing high rates of land use changes during the last decade, due to industrialization (Figure III.7).

The Taubaté region (São Paulo State) was selected as a test-site, containing approximately 780 km^2 (Figure III.8).

Computer compatible tapes (CCT) and photographic images, 1:250,000 scale, corresponding to the passes of July, 1973, September 9, 1977 and January 31, 1978 were used. Automatic and visual image interpretation techniques were applied to the LANDSAT data. The data visual analysis showed a correspondence between land-use classes and

spectral response classes. A comparison between land-use information collected from LANDSAT imagery, and aerial photography (Table III.2) demonstrated that the class "built and urban areas" was not discriminated on LANDSAT imagery, due to the difficult for setting a boundary between the expanding built area and the adjoint pastureland. The industrial area was overestimated on LANDSAT imagery because its spectral response is similar to that of the bare soil. The bare soil class includes both the bare soil and embankment areas near the cities. This class was underestimated because of its small areal extension. The crop area was identified by its location on the Paraība floodplain. A small percentage of the highlands is used for cropping. The crop area could not be associated with a single spectral response because of the timing factors, soil diversity and land management, even though it is occupied by rice plantation. The pasture class included both the natural grassland and cultivated pasture. It presents a great variety of tonal patterns on channel 5 and occupies the largest area extension. The reforestation class was identified on channel 7 because of its high reflectance (produces light gray tones). The forest class includes natural forest, but presents some inclusions of the reforestation class.

The result of visual interpretation was a land-use map of the Taubaté test-site area (Figure III.9).

TABLE III.2

PERCENTAGE OF LAND-USES OBTAINED WITH LANDSAT IMAGES AND AERIAL PHOTOGRAPHS (1977)

CLASS	AREA OCCUPIED ON AERIAL PHOTOGRAPH (Km^2)	AREA OCCUPIED ON SATELLITE IMAGE (LANDSAT) Km^2	DIFFERENCE ON MODULE (Km^2)	DIFFERENCE (%)
INDUSTRIAL AREA	3,25	7,25	4,00	123,00
BARE SOIL	4,29	1,79	2,50	58,27
CULTIVATED AREA	243,30	139,93	103,37	42,48
PASTURE	394,23	530,40	136,17	34,54
REFORESTATION	75,76	61,54	14,22	18,76
FOREST	23,70	4,13	19,57	82,50

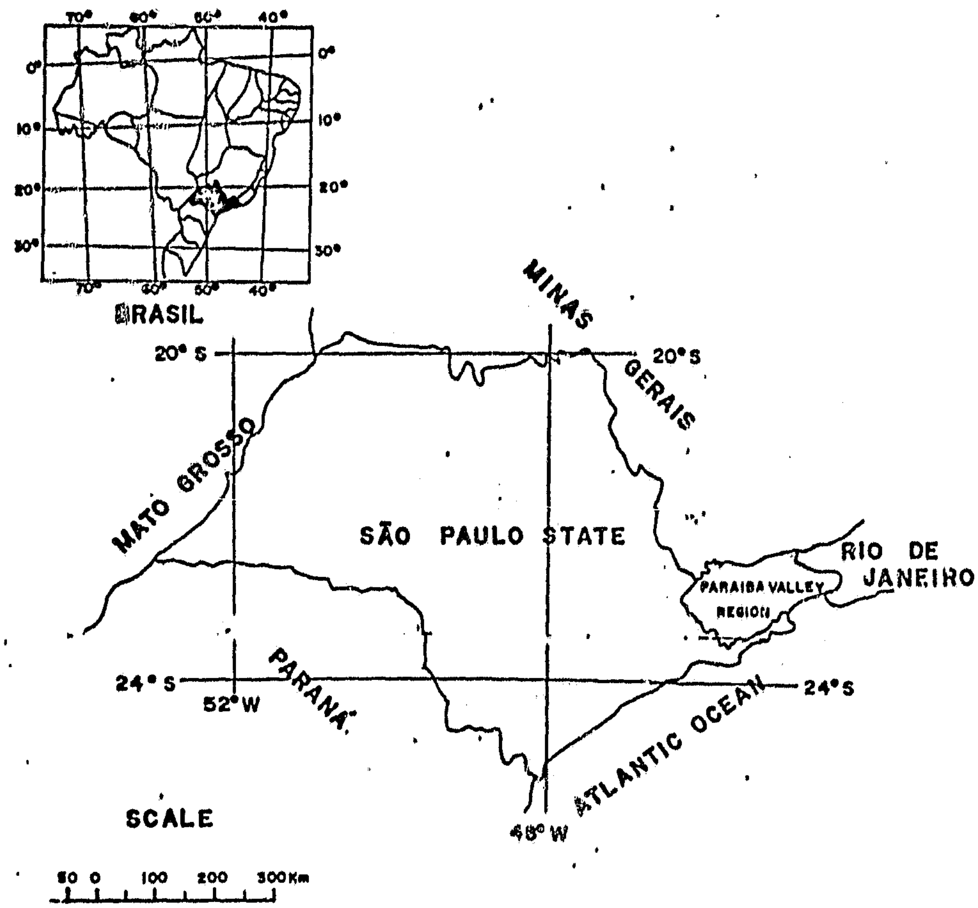

Fig. III.7 - Localization of the study area.

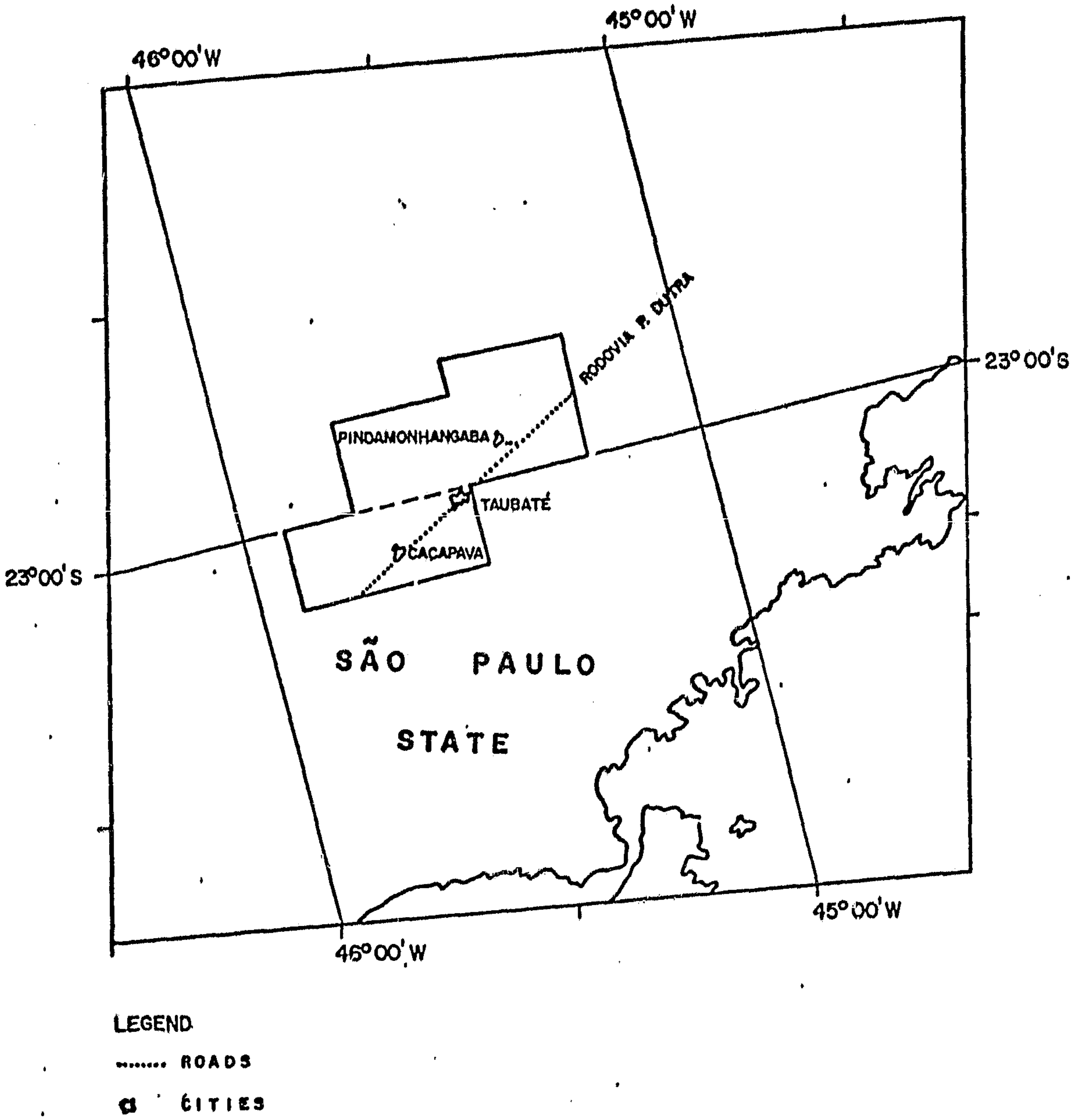

Fig. III.8 - Test-site Taubaté.

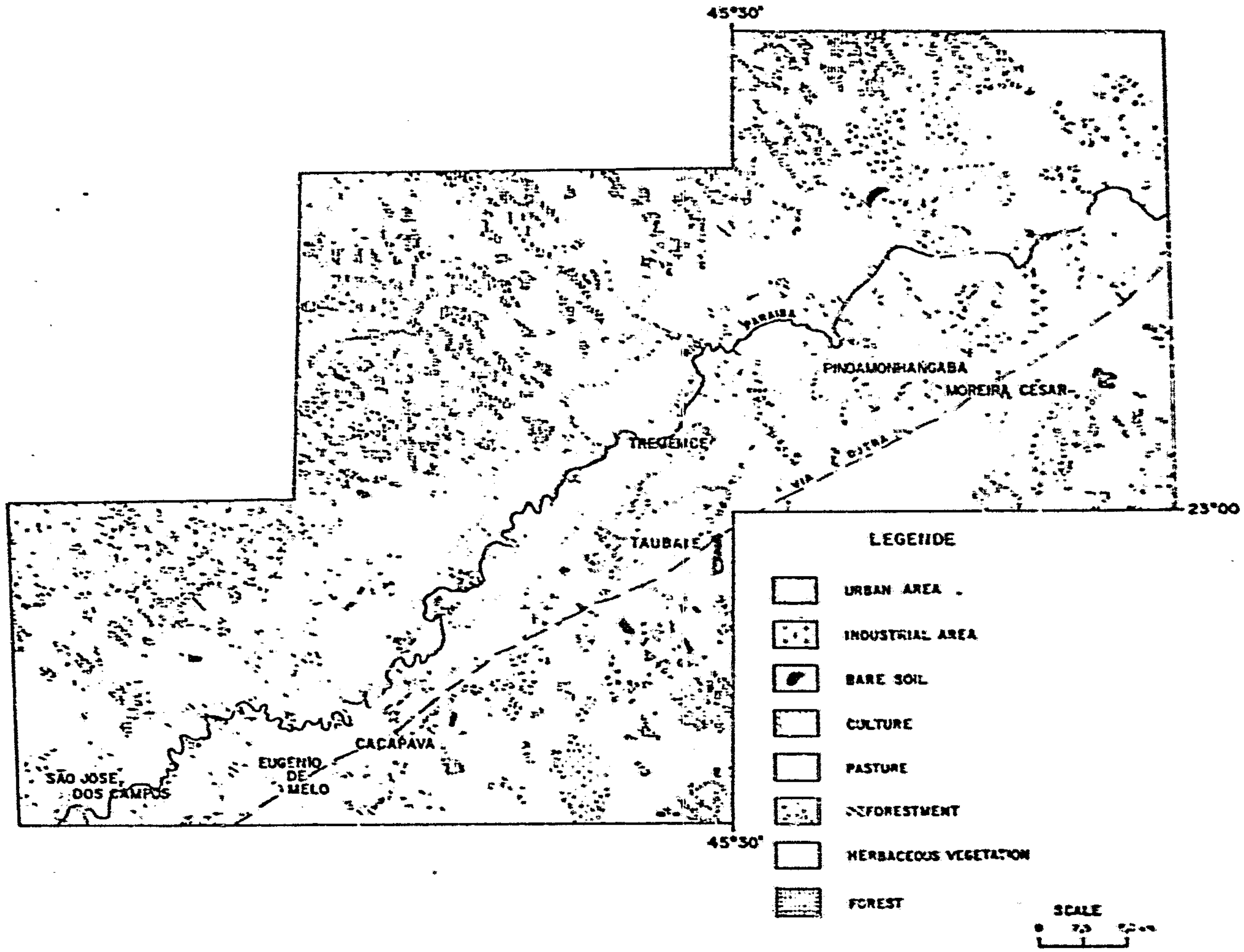

Fig. III.9 - Land-use map of test-site Taubaté (1977).

The methodology developed for the test-site Taubaté was extended to all the area under study.

Automatic interpretation was carried out using LANDSAT data for September 9, 1977. To accomplish that the test-site was by photographic control, divided into 10 modules and 2 modules were analyzed (modules 1 and 4).

These two modules were chosen because they have similar relief characteristics, but different land-use classes. The areas were at the same scale as the land-use map obtained by aerial photographs, namely 1:50.000. The automatic analysis in the IMAGE-100 system was made using the Maximum Likelihood Algorithm.

.The calculation of the classification precision was made in two forms:

1) Intersection of the classification results of the area under study with the test-site of each class analyzed was made using the program of area calculation; and

2) Comparative analysis between the total area obtained at each land-use class by automatic classification and the total of each class was obtained by conventional aerial photography.

The omission and commission errors obtained for the analyzed modules are shown on Tables III.3 and III.4.

TABLE III.3

ERRORS OF OMISSION AND COMMISSION FROM LAND-USE CLASSES (MODULE 1)

CLASS	ERROR (%)	
	OMISSION	COMMISSION
BARE SOIL	43	4
CULTIVATED AREA 1	30	1
CULTIVATED AREA 2	15	7
PASTURE	4	2
REFORESTATION	33	6
FOREST	44	8

TABLE III.4

ERRORS OF OMISSION AND COMMISSION FROM LAND-USE CLASSES (MODULE 4)

CLASS	ERRORS (%)	
	OMISSION	COMMISSION
URBAN AREA	19	1
INDUSTRIAL AREA	77	1
BARE SOIL	62	4
CULTIVATED AREA 1	38	9
CULTIVATED AREA 2	39	6
PASTURE	10	3
REFORESTATION	58	4
FOREST	39	1

The smallest omission errors were observed at the pasture class because it presents well defined spectral characteristics with medium gray level at the four LANDSAT spectral channels. The largest omission error was found at the class "industrial area" because of the spectral superposition of this class with the classes "urban area" and "bare soil".

Table III.5 shows the percentage of area occupied by land-use classes using data from satellite and airplane.

TABLE III.5

PERCENTAGE OF AREA OCCUPIED BY LAND-USE CLASSES USING LANDSAT AND AIRPLANE DATA - (SEPTEMBER 1977)

CLASS	AREA (%)			
	MODULE 1		MODULE 4	
	AERIAL PHOTOGRAPHS	LANDSAT DATA	AIRPLANE	LANDSAT DATA
URBAN AREA	-	-	20,62	11,97
INDUSTRIAL AREA	-	-	0,58	1,85
BARE SOIL	0,39	0,01	0,32	1,86
CULTIVATED AREA	24,50	24,56	22,96	19,52
PASTURE	69,07	58,38	47,36	45,74
REFORESTATION	2,22	11,84	5,61	7,74
FOREST	3,82	5,21	3,35	11,32

It is worthwhile to mention that among occupied area the classes "pasture" and "cultivated area" showed minor differences between data obtained by airplane and LANDSAT.

The results showed that LANDSAT data can be used for land use surveys. The accuracy of this methodology depends on the physical features of the area under study and the complexity of land occupation.

On the highlands the shadow effects make the identification of land-use classes difficult and contributes to increase the commission errors.

This methodology is being applied again in another region in order to evaluate the effects of physical and cultural features of land-use classification accuracy.

With LANDSAT data it is possible to obtain large land-use classes. At this level it is difficult to associate land-use classes to only one spectral class.

The utilization of gray levels as data classification criteria in visual interpretation is not sufficient, even when one uses multispectral information resulting from the combinations of channels 5 and 7.

The fragmentation and diversity of land-use in the study area make the mapping of classes a difficult task to perform.

With automatic classification where only the variable gray level is used, the number of classes obtained is related to the spectral variation of the targets.

Conventional aerial photographs and ground observations were also necessary when developing the methodology.

The use of LANDSAT data to monitor land-use is of great interest to large area economical planning and is done with a reasonable cost when compared with other conventional techniques.

3.6 - DYNAMIC STUDY OF THE UPPER SÃO FRANCISCO RIVER AND THE TRÊS MARIAS RESERVOIR, USING ORBITAL IMAGES.

(by Tania Maria Sausen, Instituto de Pesquisas Espaciais)

Because of man's increasing need for water and energy he has built up artificial water reservoirs using them for water supply and to generate electricity. These water reservoirs can also be used to regulate river discharge, allowing the irrigation of large areas.

So it is of utmost importance to preserve the water reservoirs controlling the negative factors that reduce their longevity. Among these negative factors, the transportation of solid particles from the drainage basin into the reservoir is of great concern because it produces silting problems within the reservoir.

According to the technical reports prepared by the Três Marias Reservoir Administration (Minas Gerais, Brazil), a concentration of suspended sediments was observed in certain points of the reservoir indicating possible silting problems occuring there. (Figure III.10).

Several authors emphasized that the reflectance data shown by LANDSAT-MSS imagery at different bands of the electromagnetic spectrum, present a high correlation with the amount of suspended sediments. The repetitiveness and the overall view offered by LANDSAT data, enable a fast and precise study of the effects and consequences of the discharge of sediments into man-made lakes.

The objective of the present work was to develop a methodology to use LANDSAT imagery to study the concentration of suspended sediments in the surface water layer of the Três Marias Reservoir, comparing it with its' drainage basin.

This study is part of a larger research project, developed by INPE in agreement with CODEVASF (Companhia de Desenvolvimento do Vale do São Francisco), the agency responsible for the administration of Três

Marias reservoir.

MSS-LANDSAT imagery, bands 4, 5 and 7, scale 1:500.000 for the rainy and dry season, coverage from 1973, 1975, 1977 and 1978 were used. This allowed a temporal analysis of the area studied in a 5 year period.

Initially, a visual analysis of LANDSAT imagery was carried out to obtain information about the drainage net, relief dissection patterns and land-use within the drainage basin area of Três Marias reservoir.

The Multispectral Image Analyzer (System IMAGE-100) was used to carry out the automatic interpretation of orbital data for estimating the concentration of suspended sediments on the surface water layer during the dry and wet season of the 5 year period mentioned above. To accomplish this analysis two computer programmes were used: the scale programme (D2IQIO) for enlargements of parts of the reservoir and the classification programme for gray levels by maximun likelihood (MAXVER)

Field work was carried out at two periods (March/April and August/September, 1978) to obtain data on Secchi depth and water reflectance "in situ", at pre-determined points in the reservoir. Furthermore, data on geology, geomorphology, soils, land-use and vegetation, from the drainage basin area were obtained.

From the analysis of the data, the following significant results were obtained:

- Considering simultaneously the human and physical variables acting on a drainage basin, it is possible to determine the main factors influencing such a basin, as well as to evaluate the sedimentation processes which can reduce the volume of the reservoir.

- The spectral characteristics of LANDSAT/MSS data can help to study

the dispersion of suspended sediments in a reservoir.

- The repetitiveness of LANDSAT imagery allowed various analysis of the reservoir area during the dry and wet seasons.

- The automatic analysis of MSS/LANDSAT data allowed a classification of the surficial water layer of Três Marias Reservoir according to the different concentration of suspended sediments. Twelve thematic classes for the rainy season and eight classes for the dry period were obtained.

- The correlation analysis of gray levels from the images and the data on Secchi depth, showed that the latter ones are inversely proportional to the gray levels (Figure III.11).

- MSS Band 5 presented the highest correlation between gray levels and Secchi depth (-0,89 during the rainy season and -0,96 during the dry season).

- It was observed, after correlation analysis between gray levels and "in situ" water reflectance, that they were directly proportional; and MSS band 5 presented the highest correlation coefficient (0,96 during the rainy period) (Figure III.12).

- Considering the results obtained, one can conclude that, for the Três Marias Reservoir, the predatory human occupation on its' drainage basin is the main factor responsible for the origin of the sedimentary load coming into the lake.

The project described above had a duration of three years and six months. Because of the large extension of the area studied (about 48,000 Km^2), it would be almost impossible to do it in a shorter time using any other conventional method.

Since the sediment transportation has a dynamic character, the repetitiveness of LANDSAT imagery allows a periodic study of the

process.

However, the presence of cloud cover especially over water bodies was the main difficult found when using the satellite data.

Fig. III.10 - Tres Marias Reservoir - Study Area

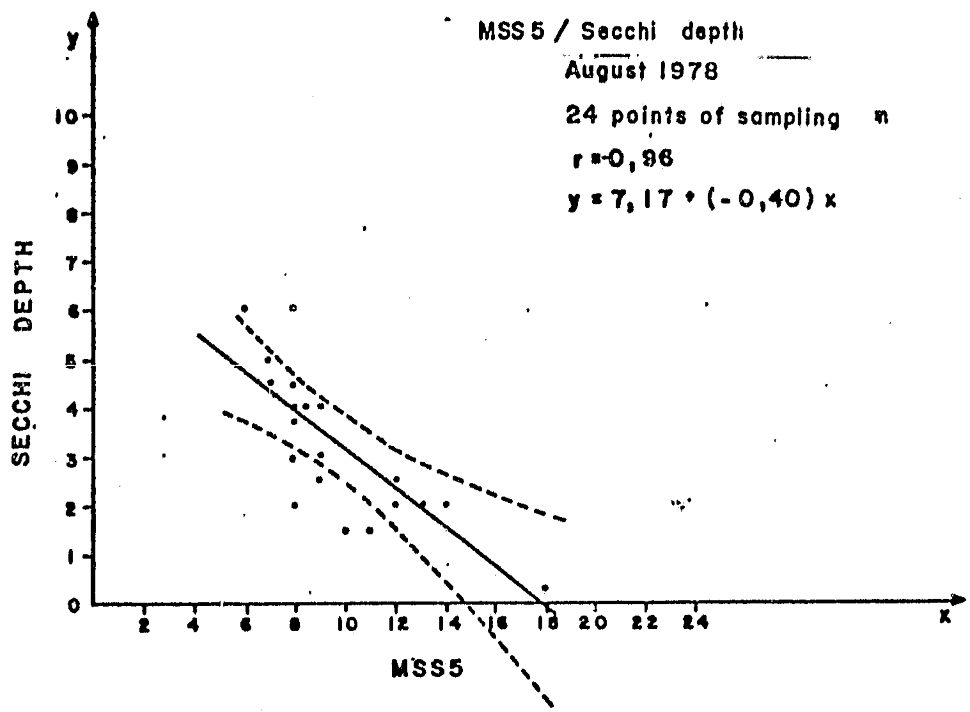

Fig. III.11 - Correlation between gray levels and Secchi Depth

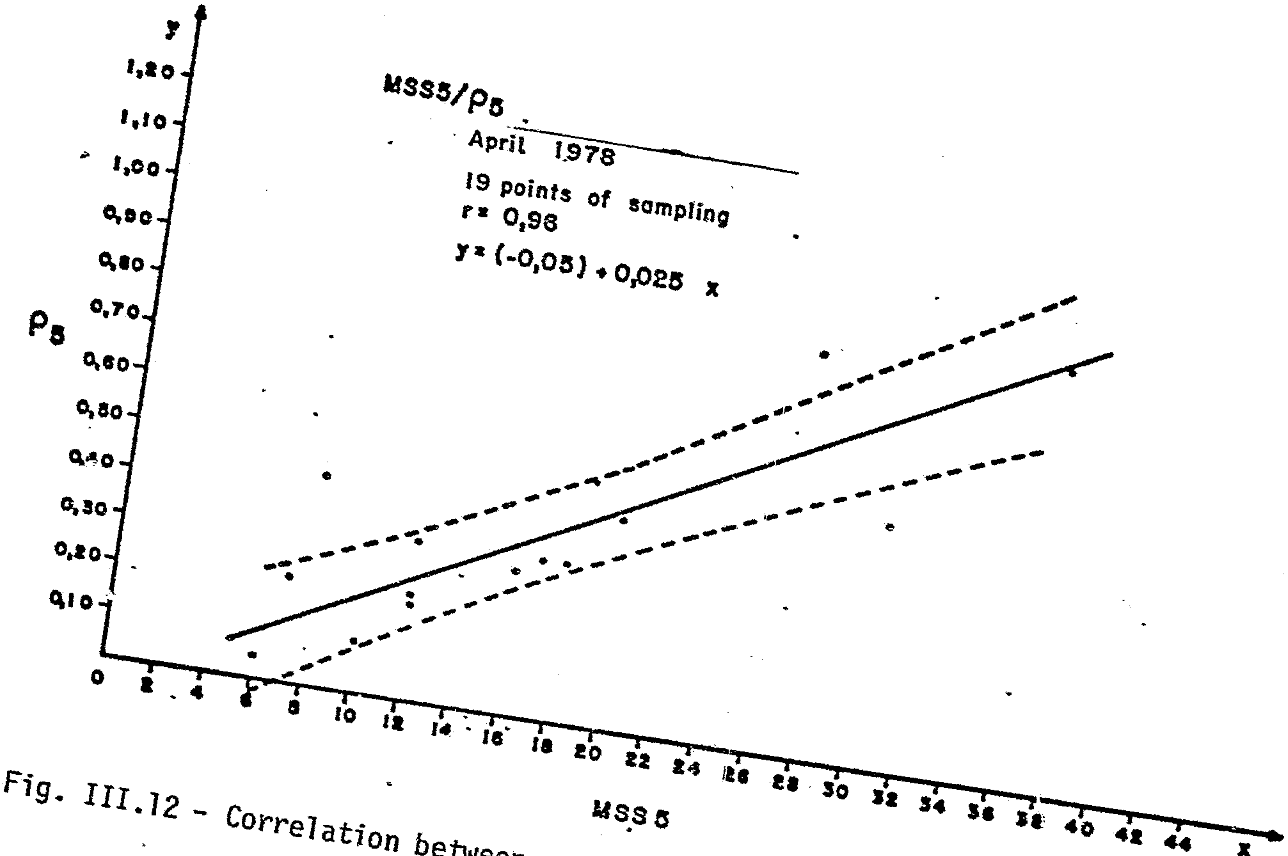

Fig. III.12 - Correlation between gray levels and "in situ" water reflectance.

3.7 - APPLICATION OF SATELLITE IMAGES TO CARTOGRAPHY

(by Márcio N. Barbosa and José Luiz B. Aguirre, INPE)

Brazil is a very large country with vast extensions of land still very poorly mapped. Conscious of this problem, the Government has established a Cartography Dynamization Plan with the objective of having the country fully mapped in the scale of 1:250,000 by the year 1983.

This represents a huge investment when conventional methods are used. With this in mind, studies have been carried by the Brazilian Institute of Space Research (INPE), in collaboration with other Government agencies related to mapping activities, to set up methods of utilizing remote sensing satellite data (presently of the LANDSAT series) to support the job.

These data offer some shortcuts which are extremely convenient to the application, besides the substantially lower cost: they can be used almost directly as a planimetric base for charts, since the Earth is seen from the spacecraft from a large distance and with a relatively narrow angle (nominal max. 5.78^{o} deviation from vertical), and also that the spacecraft is reasonably stable in orbit. The final result is the acquisition of nearly ortographic images, with low internal distortions, what simplifies enormously the photogrammetric problems of planimetric cartography, Another important point, of course, is the regular availability of the data, allowing dynamic updating land features changes.

Two pilot projects have been established, with two different agencies: the Army's Geographic Services Directory (DSG) and the Air Force's Directorate for Electronic and Flight Protection (DEPV), to produce, respectively, 1:250,000 Topographic Image Maps and 1:250,000 Aeronautical Charts.

The studies and improvements carried out by INPE towards enhancing the geometric quality of LANDSAT images yielded internal accuracies in the range of 100 to 150 meters, which were considered enough for the projects.

The inputs that INPE provided to the chart production process were mosaics of 2 spectral bands made of only two LANDSAT images each, to cover the area of one 1:250,000 sheet. These mosaics were photographed at the original 1:1,000,000 scale and the negatives obtained were enlarged and rectified through conventional methods to the 1:250,000 scale in ZEISS SEG V enlarger rectifier. This resulted in two positives for color separation and accomplishment of the remaining operations which would include addition of the symbolization and theme information. The final products, both in the UTM projection, were:

- for the DSG - and Image Map from the area of Brasília, including LANDSAT data as planimetric base and theme information extracted from 1:1,000,000 already available maps,
- for the DEPV - an Aeronautical Chart from the area of Volta Redonda, including LANDSAT data as planimetric base and theme information extracted from LANDSAT data and available Aeronautical Charts in other scales. This chart was presented during the 14th International Congress of the ISP at Hamburg (West Germany) in July, 1980. A reduced photographic copy is in addendum.

Besides the mosaics, INPE also provided to the agencies involved in the pilot projects the necessary advice for handling satellite data in graphic works and today they are self-sufficient in these activities.

The main problems faced in matching the traditional technology with this new one occured in the graphic reproduction area: (1) the color selection process to avoid the obscuration of the theme information, and (2) the necessary change in standard symbology to

avoid overloading some areas with information, since the terrain information given by LANDSAT data is already dense.

Another kind of problem (mostly restricted to INPE) was that, by the time of the pilot projects were under way, INPE did not have implemented , in its processing facility, the "Precision" models, where ground control point information are used to generate the original images in the UTM projection and with enhanced accuracy, Therefore, to carry out the experiments, INPE decided to to use the bulk processing technique (with removal of first-order systematic errors, but still in the Space Strip Perspective projection), while spending a parallel effort to finalize implementation of the Precision processing model. This was the reason why a rectifying step in the enlarginh process mentioned above was necessary. Today, the Precision processing model is in its final implementation phase.

The costs related to these experiments were covered by each one of the parts, from their own budgets. It must be pointed out that the cost to produce the Volta Redonda Aeronautical Chart has been estimated by DEPV as being one-fourth (1/4) of the cost using conventional methods.

Due to the encouraging results achieved and to allow reaching an operational stage Memoranda of Understanding were negotiated and signed between INPE and the two mentioned agencies in order to produce satellite-based maps.

With this engagement, INPE believes to be giving a valiable contribution to the Government's Cartography Dynamization Plan.

A major limitation faced today is the unability to derive altimetric information from the existing satellites data, due to the lack of stereoscopy coverage. However, in the near future, a generation of remote sensing satellites will be available to the user community, having already taken into account and removed several of the present

constraints. Early in 1984, the French satellite SPOT-1 will be launched, with capability to acquire stereoscopic coverage and resolution compatible with 1:50,000 map generation. Studies carried by the French space agency CNES estimate that the selling price of the high-resolution SPOT data will be around 1/10 of the price of equivalent high-altitude airborne photography for the same area covered.

Besides that, U.S. are seriously considering the launching, in 1986, the MAPSAT series, which will also be capable of stereoscopic coverage, with special characteristics that will allow automated altimetry restitution.

Airborne photography has given cartography its first big push. It is believed that the world is today at the edge of a new incoming revolution towards making substantially ease the universal job of having planet Earth well known and up-to-date in charts.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

CONCLUSIONS

Up till now, near a hundred methodologies have been developed and perhaps other applications aside the ones discussed in last chapter might present a greater interest to the reader.

But the application described in this paper are examples of the work that is presently under way in a country that has in the last eight years devoted a great attention to the utilization of remote sensing techniques for solving its national problems.